Androscoggin River and Gulf Island Pond
Data Report
Draft
Nov 2004

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DEPLW-0676

Executive Summary

1. A major sampling effort was undertaken on a 107-mile segment of the Androscoggin River from Berlin, NH to Lewiston, ME in the summer of 2004. The lower 14 miles of this segment is a large impoundment called Gulf Island Pond that contains the areas of water quality problems.
2. The sampling effort was a voluntary cooperative effort of three paper mills that discharge to the Androscoggin, the Androscoggin Lake Improvement Corp., and DEP.
3. The lower four miles of Gulf Island Pond is on Maine's 303d list of non-attainment segments. In the summer the deeper portions of the pond in this area fail to meet dissolved oxygen criteria for class C waters. Nuisance summer algae blooms form in Gulf Island Pond primarily from phosphorus inputs of point source discharges.
4. A major purpose of the sampling effort was to document the extent of improved water quality during the time when paper mills were undergoing voluntary phosphorus discharge reductions.
5. The summer of 2004 was wet and cool and not ideal for judging worse case water quality conditions that are ordinarily experienced in dry and warm summers.
6. Water quality findings for the summer of 2004

- All dissolved oxygen criteria were maintained in the river from Bethel to Turner
- Minimum DO criteria and monthly average DO criteria were not met in the lower three miles of Gulf Island Pond in 62% and 70%, respectively of the sampling days.
- Class B minimum DO criteria on the Dead River were met at Route 106 but not met in 7 of the 11 days sampled below the dam in Leeds
- On Gulf Island Pond widespread algae blooms were observed on only 1of the 12 sampling days. Blooms of a very localized nature occurred on three additional sampling days.
- Chlorophyll-a analysis exceeded the algae bloom threshold of 12 ug/l currently used in MDEP policy in only 5 of the 65 samples analyzed on the pond throughout the summer.
- No algae blooms were observed on the Dead River. Chlorophyll-a exceeded 12 ug/l in 2 of the 8 days sampled.
- A consistent relationship of elevated chlorophyll-a readings and observed algae blooms was not apparent in the data on Gulf Island Pond.

7. Comparison of 2004 data to historic data

- River true color levels measured below Maine paper mill inputs are at least 28% lower than levels measured in 1989.
- River total phosphorus and orthophosphorus levels measured at the entrance to Gulf Island Pond were 38% and 70% lower, respectively, than levels measured in August of 2000.
- Algae blooms were not totally eliminated in 2004, but the levels of algae that occurred on Gulf Island Pond were lower and blooms were less frequent.
- The dissolved oxygen continuous monitoring undertaken at the dam indicates that there is no trend of either diminishment or improvement of oxygen levels in the deeper areas of the pond since 1998.

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Introduction

This report focuses on a data collection effort undertaken on the Androscoggin River in the summer of 2004 from Berlin NH to Lewiston, ME encompassing 107 river miles. The lower 14 miles of this segment is a large impoundment called Gulf Island Pond that contains the areas of water quality problems. The majority of the sampling effort was financed by the three paper mills (Nexfor Fraser of Berlin, NH; MeadWestvaco of Rumford, ME; and International Paper of Jay, ME) that discharge to the Androscoggin River in this segment.

The water quality monitoring was a voluntary effort by the paper mills to determine the extent of the improvements that could be realized to water quality in Gulf Island Pond with voluntary phosphorus discharge reductions undertaken by the mills in the summer of 2004. The majority of the sampling was undertaken by Acheron Engineering of Newport, ME. MDEP and other volunteer stakeholders assisted in the effort with the sampling of the river above Gulf Island Pond. The study was planned collectively by the paper mills, Acheron Engineering, and MDEP.

The Androscoggin River has had a long history of very poor water quality. A low point was reached in the 1960's when it was recognized as one of the ten most polluted rivers nationally. Considerable cleanup progress has been accomplished over the years up to a point where dissolved oxygen criteria are met everywhere except in the deeper portions of Gulf Island Pond for certain times of the year.

The lower four miles of Gulf Island Pond is on Maine's list of waterbodies that do not attain their water quality classifications (303d list). Dissolved oxygen is listed as the parameter of non-attainment and both point and non-point sources are cited as the reasons for the non-attainment. Class C minimum dissolved oxygen criteria currently require that levels be maintained at a minimum of 5 ppm and 60% of saturation and a monthly average of 6.5 ppm. Persistent and frequent algae blooms that develop on the pond every summer is another water quality issue that must be addressed. As a result of being on the 303d list, the Federal Clean water Act requires that a Total Maximum Daily Load[1] (TMDL) be developed to bring this water body into compliance with class C water quality standards. This TMDL has a high level of priority on the 303d list with a projected completion date at the end of 2004.

A scientific analysis was undertaken by DEP from Aug 2000 to June 2002 (see Androscoggin River Modeling Report and Alternative Analysis, MDEP, June 2002) that involved the verification of an older water quality model developed in the 1980's to modern data. In modeling subsequent to this, a preliminary TMDL for Gulf Island Pond has been developed by MDEP. The data collected in the summer of 2004 will serve as a check on the modeling undertaken to date and may in some cases provide information for

[1] A TMDL is a plan of action for cleanup of a water body that currently doesn't meet water quality standards, which should result in a reasonable assurance that criteria will be met after implementation of the plan. The plan typically involves reductions of point and/or non-point sources of pollution and includes an adequate margin of safety related to the degree of uncertainty in the scientific analysis.

data gaps identified in the modeling process. For example, the phosphorus data collected in 2004 from the river in Berlin to the entrance of Gulf Island Pond will update model input rates for orthophosphorus that is assimilated by bottom attached plants.

Technical Design of Study

The study involved weekly sampling of the following: Androscoggin River at eight locations from Berlin NH to Turner, ME; Gulf Island Pond at five locations; and the Dead River at two locations (figure 1). The sampling on the Androscoggin River and Gulf Island Pond was originally planned to begin on June 16 and continue every Wednesday until September 15 of 2004. There was a possibility that some of the days could be cancelled by DEP if high river flow or large runoff events occurred prior to or during the scheduled sampling dates. Such events would make the river unrepresentative of modeled conditions so the data collected would not be useful. During August and early September of 2004, many precipitation and runoff events occurred. This resulted in canceling the sampling at all locations on September 15, and at river locations on August 18, 25 and September 8.

The Dead River was usually sampled on the day following the Androscoggin River sampling or every Thursday. The two locations sampled were Route 106 and below the dam in Leeds. The sampling was a voluntary effort undertaken by ALIC (Androscoggin Lake Improvement Corp.) with the laboratory analysis funded by MDEP.

The ambient sampling parameters typically included dissolved oxygen and temperature twice per day (in the early morning and mid afternoon) and phosphorus at all locations, and nitrogen, chlorophyll-a, and true color analysis at some locations. Secchi depth transparency was taken where there was adequate depth (Table 1).

All of the sampling in Gulf Island Pond was undertaken by Acheron Engineering personnel under contract to the three paper mills. The sampling for laboratory analysis was similarly undertaken by Acheron. DEP personnel and volunteer stakeholders undertook the sampling of dissolved oxygen, temperature, and secchi depth transparency at the river locations from Bethel to Turner. All of the laboratory analysis was done by Acheron except the chlorophyll-a analysis, which was done by HETL (Health and Environmental Testing Laboratory, Maine Department of Human Services) in Augusta.

The sampling followed DEP standard operating procedures (SOP's). Dissolved oxygen meters were crosschecked before and after each sampling run and calibration was checked periodically throughout each sampling day. Dissolved oxygen and temperature are measured as 1 meter profiles from the water surface to the last full meter of water depth above the pond bottom. The early morning sampling starts at dawn with a target completion time of 8 AM and the mid afternoon sampling begins at 1 PM.

Table 1 Summary of Sampling Locations and Parameters

Location	Total Kjeldhal Nitrogen	Ammonia Nitrogen	Nitrite and Nitrate Nitrogen	Total Phosphorus	Ortho - Phosphorus	True Color	Chlorophyll-a	Dissolved Oxygen Temperature	Secchi Depth
	TKN	NH3-N	NO2+3-N	TP	PO4-P		Chl-a	DO Temp	
Androscoggin River									
Berlin	1 mid-day								
Shelburne North Rd Bridge				1 mid-day					
Bethel Rte 2				1 mid-day				2 / day AM/PM	
Rumford Canal Bridge	1 mid-day								1/day*
Dixfield Bridge				1 mid-day					
Riley Dam	1 mid-day								1/day
Livermore Falls Rte 4 Bridge				1 mid-day					1/day*
Twin Bridges (Rte 219)	1 mid-day								
River Duplicate	0.5 times / week								
River Field Blank									
Gulf Island Pond									
Turner Bridge	1 / day afternoon							2 / day AM/PM	
Upper Narrows									
Lower Narrows									
GIP4									
Deep Hole									
Pond Duplicate	0.5 times / week			1 / week		0.5 times / week		1 / week	
Pond Field Blank									
Dead River									
Route 106				1 / day AM bimonthly			1 / day AM Bimonthly	2 / Day AM/PM	
Below Dam at Leeds									

*Due to difficult boat access, sample locations for secchi depth were moved from Rumford Canal bridge to 0.5 miles above Virginia Bridge and from Livermore Falls bridge to below Pine Island. The river depth was too low to sample secchi depth at Bethel, D

Core samples (integrated depth) were taken for laboratory analysis in Gulf Island Pond at a depth equal to twice the secchi depth transparency measurement. A sludge judge or tube sampler is typically used for core sampling. Many cores are composited in a bucket so that all the necessary sample containers at any given location can be filled with a single filling of the bucket. Both the core sampler and bucket are rinsed three times at each sample location prior to collecting the actual sample water for laboratory analysis. In the river, samples were taken at mid depth whenever the total river depth was less than 2.5 meters and composited at ¼ and ¾ of the depth whenever the total river depth was greater than 2.5 meters.

A final component of the study involved an aerial survey by DEP to observe algae blooms in Gulf Island Pond and the Dead River. Aerial photographs were taken from the plane to document the coverage of any blooms that were observed. The plane flights were made in the afternoon of the scheduled sampling days. A summary report of the aerial flight together with the aerial photos is available separately from DEP. Observations of algae blooms were also made by field sampling personnel from a boat.

Hydrologic Data and Sampling Conditions

River flow data is available at USGS gages within the river segment of interest in a number of locations. On the Androscoggin River, USGS gages are located at Errol, NH; Gorham NH; Rumford, ME and Auburn, ME. There are also gages located on the following tributaries: the Wild River at Gilead; the Ellis River at South Andover, Swift River near Roxbury, and Nezinscot River at Turner Center. The river gage at Rumford is in a central location within the segment of interest and provides a good reference point for flow conditions.

For the purposes of water quality evaluations, it is desirable to conduct river sampling under a critical condition of extended low flow and high water temperatures. If data indicate that water quality criteria can be maintained under this critical condition, it can be concluded that water quality should be acceptable under almost any conditions.

A plot of daily flow conditions at Rumford for the summer of 2004 (Figure 2) indicates that many runoff events occurred this past summer. A major runoff event occurred in early June in which the daily average river flow peaked at slightly over 4000 cubic feet per second (cfs). This was followed by an extended dry period from mid June to mid-July in which 7Q10[2] was nearly achieved. This was followed by a series of runoff events from mid-July through early September, the most notable being when the daily average flow peaked at 8100 cfs on August 15 and 6770 cfs on September 11. In contrast, something close to the 7Q10 of 1600 cfs is desirable sampling conditions. These high river flows resulted in the canceling of river sampling on August 18, 25, and September 8. Sampling in both the river and the pond was canceled on September 15.

The water temperature at Turner Bridge is a good reference point for critical temperature. Warmer temperatures here indicate that water transport is typically across the surface water layers and mixing to the pond in the deeper portions is inhibited. This results in lower deep water dissolved oxygen levels (see Androscoggin River Modeling Report and Alternative Analysis, June 2002, MDEP, pp8-13 for a more detailed explanation of this flow transport phenomena in Gulf Island Pond). Warmer water temperatures also lead to lower dissolved oxygen readings due the following scientific relationships to higher water temperature: the lower solubility of oxygen in water, the increase in the rates of oxygen demand from the sediments and water column, and the increase in the rates of algal growth and respiration.

Continuous data is also available at Turner Bridge in the summer at a depth approximately 0.5 meters from the river bottom. The monthly average temperatures in the summers from 1998 to 2004 are used for comparison purposes. When the

[2] The 7-day 10-year low flow (7Q10) is the lowest 7-day average flow expected to occur at a frequency of once in ten years. 7Q10 is the critical low flow condition used to evaluate the water quality impact of point source discharges to their receiving water.

temperature data are compared, it can be observed that the coolest water temperatures were observed in the years 2000 and 2004 followed by 1998 and the warmest water temperatures 1999, 2001, 2002, and 2003. Even though good critical flow conditions were reached early in the summer of 2004, the water temperatures that occurred during that time were cooler than desirable for achieving a worse case condition. It can be concluded that the summer of 2004 was wetter and cooler than most summers, and did not result in the conditions that are ideal for evaluating water quality directly with the data. However the data are useful for calibrating the water quality model to algae conditions under reduced phosphorus loading to Gulf Island Pond. This should ultimately result in improved model predictions under reduced phosphorus loading.

Ambient Chemical Data

Dissolved Oxygen

A waterbody must have adequate levels of dissolved oxygen (DO) to support a healthy aquatic ecosystem. Sources of dissolved oxygen depletion could include organic matter from both point and non-point sources of pollution, and to a lesser extent natural sources. The organic matter causing the depletion of oxygen could occur in the water column as dissolved and/or particulate matter or as bottom sediment from particulate matter that has settled to the river bottom. When significant levels of algae are evident, a diurnal trend of low early morning DO from extended nighttime respiration and high afternoon DO from photosynthesis occurs. Each water quality classification in state law specifies a particular level of dissolved oxygen that must be maintained.

Dissolved oxygen and temperature were measured as one meter profiles in the pond twice per day in the early morning and mid afternoon to capture the lowest and highest readings, respectively. In the river, it was often difficult to obtain profiles from bridge sites, due to the scoping of the probe cable in strong river currents, particularly during the higher river flows. Readings of dissolved oxygen and temperature should not vary significantly in the vertical when experiencing strong currents due to mixing, so the omission of the deeper water readings should not be critical. In this situation, readings were taken as deep as possible without significant scoping of the probe cable.

A summary of the Androscoggin River dissolved oxygen data plotted as a time series over the entire summer (Figure 4) indicates that minimum dissolved oxygen criteria were easily met at all locations. In Bethel, the river is class B requiring that the daily minimum dissolved oxygen be not less than 7 ppm and 75% of saturation. At all other locations, the river is classified as C requiring that the daily minimum dissolved oxygen be not less than 5 ppm and 60% of saturation. Although not plotted, the monthly average class C dissolved oxygen criterion of 6.5 ppm was also easily met at all water temperatures, since the majority of the daily minimums exceeded 6.5 ppm.

The diurnal dissolved oxygen measured as a difference of the maximum and minimum readings taken at mid-afternoon and early morning are a good indication of the degree of algal and/or plant activity. In flowing waters, bottom attached plants are the primary mechanism driving diurnal DO fluctuations, and in sluggish and impounded waters,

phytoplankton or floating algae are the primary mechanism. The former are not transported with the river flow, and the latter are transported downstream with the river flow.

The diurnal DO fluctuations of Androscoggin River locations are generally rather low compared with other river systems that DEP has studied involving river segments containing point source inputs. Diurnal DO averaged less than 1 ppm at all locations and the maximum fluctuation in any given week did not exceed 2 ppm (figure 5). The diurnal DO fluctuations are greater in flowing sections such as Bethel, Dixfield, and Twin Bridges, indicating that bottom attached plants rather than phytoplankton are the primary source of diurnal DO fluctuations. The low diurnal fluctuations are consistent with field observations, which indicated that the levels of bottom attached plants were low on the Androscoggin River during the summer of 2004.

In Gulf Island Pond, the river is classified as C requiring the daily minimum dissolved oxygen not be less than 5 ppm and 60% of saturation. New legislation states that dissolved oxygen readings below a point 0.5 meters from the bottom of the pond and below the point of thermal stratification (bold face line in Figure 6) should not be considered in a compliance evaluation for dissolved oxygen. New legislation to be considered, that is currently DEP policy, requires that the monthly average dissolved oxygen concentration of 6.5 ppm apply only at temperatures less than or equal to 22 ^{o}C on the Androscoggin River.

Schematics of the pond indicating the location of the thermocline, measured concentrations of phosphorus and chlorophyll-a at each sampling location, and the estimated areas on non-attainment of minimum DO criteria (indicated as shaded areas) are presented in the appendix for each sampling day. A summary of the Gulf Island Pond dissolved oxygen data plotted as a time series over the entire summer Vs the compliance depth (Figure 6) indicates that both minimum dissolved oxygen (DO) criteria and monthly average DO criteria were not met on several occasions throughout the summer. The non-attainment typically occurs at the lower portions of the pond in deeper waters.

At the Deep Hole location, minimum DO criteria were not met in 8 of the 13 weeks (62%) sampled with the largest amount of non-compliance readings occurring on July 7 (7 readings from 13 to 19 meters of depth). The monthly average DO criteria were not met in 7 of the 10 weeks (70%) evaluated with the largest amount of non-compliance readings occurring on July 14 and 21 (9 readings from 11 to 19 meters of depth).

At the GIP4 location, minimum DO criteria were not met in 5 of the 13 weeks (38%) sampled with the largest amount of non-compliance readings occurring on July 7 (7 readings from 13 to 19 meters of depth). The monthly average DO criteria were not met in 5 of the 10 weeks (50%) evaluated with the largest amount of non-compliance readings occurring on July 14 and 21 (9 readings from 11 to 19 meters of depth).

At the Lower Narrows location, minimum DO criteria were not met in 5 of the 13 weeks (38%) sampled with the largest amount of non-compliance readings occurring on July 7

(7 readings from 13 to 19 meters of depth). The monthly average DO criteria were not met in 5 of the 10 weeks (50%) evaluated with the largest amount of non-compliance readings occurring on July 14 and 21 (9 readings from 11 to 19 meters of depth).

At the Turner Bridge and Upper Narrows locations, all DO criteria were met with the exception of one sampling event that occurred on July 7 in which minimum DO criteria were not met from 10 to 12 meters at Turner Bridge. The DO excursion at Turner Bridge may be caused by poor mixing due to geographical features. A deep hole occurs below Turner Bridge at the point of sampling. Current Maine law allows exemptions for maintaining DO criteria due to topologic isolation of such features.

The Dead River is classified as B requiring that daily minimum DO be not less than 7 ppm and 75% of saturation. A summary of the Dead River dissolved oxygen data above the point of thermal stratification plotted as a time series over the entire summer (Figure 7) indicates that minimum dissolved oxygen criteria were met at Route 106. However below the dam in Leeds, minimum DO criteria were not met in 7 of the 11 weeks that were sampled. This is the first intensive sampling effort of the Dead River by DEP, and water quality trends there are unknown.

Temperature

Temperature is ordinarily measured in conjunction with dissolved oxygen due to its correlation with DO solubility. As mentioned earlier in the report, maintaining adequate dissolved oxygen levels become increasing more difficult at higher water temperatures. A summary of the Androscoggin River water temperature plotted as a time series over the entire summer (Figure 8) indicates the trend of cooler water temperatures experienced throughout the summer of 2004. There is the expected trend of increasing water temperature in the downstream direction of the watershed. Water temperature averaged 20.7 ^{o}C at Bethel and 22.6 ^{o}C at Twin Bridges for the summer of 2004. The maximum river temperature was achieved on August 4 when daily average temperature topped out at 23.2 ^{o}C at Bethel and 26 ^{o}C at Twin Bridges.

A summary of the Gulf Island Pond depth averaged water temperatures plotted as a time series over the entire summer (Figure 9) similarly indicates the trend of cooler water temperatures experienced throughout the summer of 2004. The plots with the largest range of temperature (max and min) are areas where thermal stratification is evident. It is evident from the plots that thermal stratification occurred at Lower Narrows from the beginning to mid-summer and at the Deep Hole for most of the summer. The maximum temperature in the pond was achieved on August 4 when the depth averaged daily average temperature topped out at 26.0 ^{o}C at Turner and 22.2 ^{o}C at the Deep Hole. The

cooler depth average temperatures at the Deep Hole result from the very cool temperatures that occur below the thermocline[3] in the pond hypolimnion[4].A summary of water temperatures plotted at various depths for the Dead River also illustrates the thermal stratification that occurs at the two locations sampled (figure 10). The much lower temperatures sampled at depth indicate that the thermocline usually set up at a depth of two to three meters. The temperatures at the downstream location (below the dam in Leeds) are usually cooler than the upstream location (Route 106). The maximum water temperatures occurred on August 4, when surface layer temperatures of 25, and 23.5 ^{o}C occurred at Route 106, and below the dam at Leeds, respectively.

Nutrients

Nitrogen and phosphorus are the primary nutrients that could be controlling factors for algae growth and the development of nuisance blooms. It should be mentioned that moderate levels of nutrients and algae are desirable and, in fact, are a vital component of the food chain. It is only when nutrients reach an excessive threshold point resulting in blooms do they become objects of water quality concern.

Nitrogen and phosphorus concentration levels measured on each sampling date are plotted by river location. The summer averaged concentration level at each location is plotted as a boldface line. For these plots the trend among river locations and sampling dates can be observed. Nitrogen data is plotted as total nitrogen (TN) which is derived from the sum of Total Khejdhal Nitrogen (TKN) and nitrite plus nitrate nitrogen; and as total inorganic nitrogen (TIN), which is derived from the sum of ammonia nitrogen and nitrite plus nitrate nitrogen (Figure 11). TIN is the dissolved portion of nitrogen that is readily available for algae growth.

The summer averaged values for TN on the Androscoggin River and Gulf Island Pond varied from 0.67 to 0.96 ppm. The majority of the TN concentrations for each sampling date were clustered within a range of 0.2 to 1 ppm. For some unknown reason, the range of TN measured on June 23 and 30 at all locations (1.4 to 3.4 ppm) was much higher than the other sampling dates. The TIN on both the river and pond follows a similar trend of the TN, with the values measured on June 23 and 30 at all location being much higher than the other dates. The TIN measured on June 23 and 30 ranged from 1 to 2.2 ppm compared to a range of 0 to 0.9 on all other sampling dates. The summer averaged TIN was around 0.5 ppm $\pm$ 0.1 ppm at all locations.

[3] The thermocline refers to the horizontal plane within a water column resulting in the maximum vertical temperature gradient (defined in Maine statute as a minimum rate of change of 1 ^{o}C per meter of water depth).
[4] The hypolimnion is the volume of water within a water body contained beneath the thermocline.

The phosphorus data is plotted as total phosphorus (TP) and orthophosphorus (ortho-P) by sample location for each sampling date (Figure 12). The ortho-P is the dissolved portion of phosphorus that is readily available for algae growth. The majority of TP levels for the river and pond on each sampling date are clustered within a range of 20 to 40 ppb. The summer averaged TP ranges from 20 ppb at the background site in Berlin to about 40 ppb at Livermore Falls and Dixfield. There is a trend in both the TP and ortho-P river levels that result in significant increases in riverine levels as a result of paper mill discharges, which then decrease downstream as phosphorus is assimilated by algae and other bottom attached plants. This trend results in somewhat variable ortho-P levels longitudinally in the river that usually fall within a range of <1 (detection level = 1 ppb) to 10 ppb on any given sampling day. The summer averaged ortho-P ranged from a low of 1 ppb at Berlin to as much as 7.5 ppb at Livermore Falls and Twin Bridges, the entrance to Gulf Island Pond.

The phosphorus data sampled on the Dead River locations indicates that TP was always higher at the site below the dam when compared to the Route 106 location. The TP averaged 25 ppb below the dam and 19 ppb at Route 106 (Figure 13). Ortho-P was low at both locations (usually 1 ppb or less).

The nitrogen to phosphorus ratio can be calculated at any given location to determine which nutrient should be limiting for algal growth and hence should be regulated as a management strategy to control algae. A rule of thumb used by DEP indicates that when N/P < 10, nitrogen is usually limiting; if N/P > 20, phosphorus is usually limiting; if N/P falls in-between 10 or 20, either nutrient or possible both nutrients can be limiting. In water bodies that are colored, light could also be a limiting factor that inhibits the growth of algae. This will be discussed later in the report.

The N/P ratio of the readily available nutrients (TIN, ortho-P) is plotted for each location on each sampling date (Figure 14). It can be observed that N/P ratios for the majority of the data on each sampling date falls well over the threshold level of 20 indicating a strong phosphorus limitation for the Androscoggin River and Gulf Island Pond. The summer averaged N/P range from a high of nearly 500 at Berlin to a low of 86 at Twin Bridges and are 150 to 170 in Gulf Island Pond.

Chlorophyll-a

Chlorophyll-a is used as an indicator for the levels of water column algae biomass. Measurement of chlorophyll-a in this report is corrected for the presence of non-living cells. Corrected chlorophyll-a is the appropriate measurement for river modeling studies.

The chlorophyll-a is plotted as a time series graph (Figure 15) for the five sampling locations in Gulf Island Pond including the background location at the pond entrance (Twin Bridges). The average of all pond locations for each sampling date is indicated by a boldface line.

The highest chlorophyll-a levels measured within the pond as a whole occurred on June 23 and August 4 when the average chlorophyll-a was around 10 ppb. Maintaining river

chlorophyll-a below a range of 8 to 12 ug/l chlorophyll-a has recently been proposed by DEP as a threshold target level for eliminating algae blooms. The 2004 data indicate that a level of 12 ug/l for chlorophyll-a was exceeded in only 5 of the 65 samples taken in Gulf Island Pond throughout the summer.

Observations of algal blooms by Acheron sampling personnel within a boat on the pond and DEP personnel in a plane flying over the pond was a part of the sampling plan for the summer of 2004. August 4 was the only date, in which a widespread algae bloom was observed on the pond by people in both the boat and plane. The algae bloom on this date extended from Lower Narrows to the Deep Hole. Chlorophyll-a measurements on August 4 ranged from 10 to 19 ppb at these locations. More localized algae blooms were also observed in the pond from the plane on July 21, August 25, and September 8.

On the days when localized algae blooms were observed, the chlorophyll-a levels were typically not measured in the exact area of the blooms. Chlorophyll-a levels reported at the nearest weekly sampling locations will be referenced. It should be noted that the chlorophyll-a levels at the nearest sampling locations are not necessarily the same as chlorophyll-a within the bloom. Hence it is difficult to correlate the localized blooms to any given chlorophyll-a level.

On July 21, the localized blooms were observed from the plane near the GIP4 and Deep Hole locations. Chlorophyll-a reported at those locations for that date was 8.3 and 14.4 ppb, respectively. On August 25 localized blooms were observed from the plane on either side of the islands near GIP4. The chlorophyll-a reported at GIP4 for that date was 4.8 ppb and the highest level reported on the pond was 5.6 ppb at the Deep Hole. On Sept 8, algae blooms were concentrated in a small area above the oxygen diffuser near Upper Narrows sampling location, but the chlorophyll-a reported at Upper Narrows was 2.9 ppb.

There were other somewhat elevated chlorophyll-a readings taken in which no observable blooms were reported by the plane or boat personnel. Some of these would include chlorophyll-a levels of 11.6 to 12.2 ppb from Turner to Lower Narrows on June 23; chlorophyll-a levels of 10.7 to 21.4 ppb from Turner to Upper Narrows on June 30; chlorophyll-a levels of 15.4 ppb at Lower Narrows on July 14; chlorophyll-a levels of 13.6 ppb at Lower Narrows on August 14; and chlorophyll-a levels of 10.1 ppb at the Deep Hole on September 1. Given the data this summer, there does not seem to be a consistent relationship between elevated chlorophyll-a readings and the visual observation of algae blooms.

The chlorophyll-a levels of the Dead River locations indicate elevated algae biomass occurred on July 30 and August 12 (Figure 15). Chlorophyll-a levels at Route 106 and below the dam were 16 and 17.9 ppb, respectively, on July 30 and 14.6 and 10.2 ppb, respectively, on August 12. No observable blooms were reported by the plane or field personnel for these days. The chlorophyll-a for the other six sampling days at both locations was always under 9 ppb.

True Color and Secchi Depth Transparency

Color in water may result from the presence of natural metallic ions, humus and peat materials, plankton, weeds, and industrial wastes[5]. A source of color on the Androscoggin River is paper mill waste, which may contain high levels of color when compared to what may ordinarily occur in a natural environment. Colored water can also result in an additional limitation for the growth of algae due to inadequate levels of light. True color as opposed to apparent color measures the color content of water after the removal of suspended matter. Hence, the levels of phytoplankton or other suspended solids should not affect true color determinations.

The plot of true color of both the river and pond locations (Figure 16) indicates that summer averaged background color in Berlin, NH is 35 color units which eventually increases to slightly more than 50 color units in some of the river and pond locations. Hence paper mill discharges are no longer the most significant source of true color but can collectively cause natural background levels to increase by up to 50% at some locations. Secchi depth transparency is ordinarily used in lakes as an indication of phytoplankton levels. Low water column transparency readings in a lake can usually be attributed to high plankton levels, given that water color is not elevated. In rivers, turbidity due to point source discharges and non-point source pollution during runoff events can also be an important factor affecting water transparency.

The secchi depth transparency readings in the Androscoggin River usually were in-between 2 to 3 meters (Figure 17). The lower readings experienced on September 1 were due to turbidity experienced during a large runoff event. There also appears to be a trend of diminishing transparency in the downstream direction of the river.

Gulf Island Pond secchi depth transparency readings were always in-between a rather tight range of 1.7 to 2.8 meters (figure 17). The average values for the pond for each sampling date were similarly in-between a tight range of 1.9 to 2.4 meters. When comparing the pond averaged chlorophyll-a for each sampling date to the pond averaged secchi depth for each sampling date, there appears to be a good trend of lower secchi depth transparency for those dates with higher chlorophyll-a readings. For example, the lowest pond averaged secchi depth of 1.9 meters occurred on August 4 when the highest pond averaged chlorophyll-a reading of 10.3 ppb occurred.

The Dead River secchi depth transparencies (figure 17) were usually much lower at the site below the dam than the Route 106 site. The lowest secchi depth reading of 1.3 M occurred on August 19 and 27 below the dam. The readings at Route 106 were about 1 M higher on those dates. There does not seem to be a consistent relationship between the chlorophyll-a levels and the secchi depth readings. The expected relationship is low transparency readings when chlorophyll-a is the highest. The chlorophyll-a of 1 ppb measured on August 27 below the dam is low. The secchi depth transparencies reported

[5] Standard Methods for the Examination of Water and Wastewater, 20th edition, 1998.

on the days that chlorophyll-a was the highest (July 30, August 12) were in the middle of the range observed for the summer.

Effluent Data

Effluent total phosphorus and in some cases orthophosphorus were measured by treatment plant personnel from three paper mills and four municipalities as a voluntary monitoring effort in conjunction with the river sampling. A summary of the average phosphorus discharged indicates that paper mills are the largest source of phosphorus among point sources (Figure 18). The three paper mills each averaged from 133 to 161ppd TP and 71 to 97 ppd ortho-P. Municipal discharges collectively accounted for 52 ppd TP and about 45 ppd ortho-P.

There is limited historic data for estimating prior levels of phosphorus for point source discharges. The loads used in the 2002 modeling report to estimate mill TP discharges prior to the 2004 reductions (Based upon the best available information) were in a range of 200 to 240 ppd for each mill. The 2004 phosphorus discharge levels of paper mills are a significant reduction (>1/3) from levels experienced prior to 2004. Phosphorus effluent monitoring data is plotted by day and as a 30-day running average (Figures 19 and 20). The 30-day running average gives a good indication of trends. This indicates that Fraser Nexfor's discharge of TP increased as the summer progressed and International Paper's total and ortho-P decreased as the summer progressed. MeadWestvaco's TP and ortho-P remained steady throughout the summer. Both Livermore Falls'and Rumford-Mexico's TP appeared to show a trend of slight increase as the summer progressed. The increases at the municipal plants later in the summer could be due to the increased flow volume related to precipitation events and the increased groundwater infiltration into the sewer system that is typically experienced in wet weather conditions. At the time of the writing of this report, all of the information needed to compute daily phosphorus loads was not available for the New Hampshire municipal discharges and as a result Berlin and Gorham NH are not plotted as a time series.

Comparison of 2004 Data to Historic Data

Given that point source phosphorus discharge levels were much lower in the summer of 2004 than previous summers, many may be interested in knowing whether or not the Androscoggin River's water quality is showing signs of improvement. This is usually not easy to answer with only one summer of monitoring completed. If a good critical summer of high water temperatures and low river flow was achieved, the question of whether or not the river is improving could be answered with more certainty. As discussed earlier, the summer of 2004 was wet and cool when compared to the more critical summers. However, some conclusions can still be made using the available data and best professional judgement.

Legislation enacted in 1990 limited color increases in ambient waters due to point source discharges. As a result, Maine paper mills were required to reduce the amount of color discharged. The data collected in 2004 is compared to data collected in 1989, prior to the

requirements of color reductions. The 1989 data collection effort was similar to last summer's effort in that it involved weekly sampling from June to September at a number of the same locations sampled last summer.

River flow conditions measured in 1989 at Rumford were slightly higher than 2004. The average June 1989 flow was 5744 cubic feet per second (cfs) and monthly average flows from July to Sept ranged from 2132 to 2812 cfs. Monthly average flows at Rumford from June to August of 2004 ranged from 2171 to 2710 cfs. Hence given no color reductions, color units measured in the river on the average should be slightly lower in 1989 due to the increased river dilution experienced in June of that year.

The actual data, when compared, shows that the amount of color measured in the Androscoggin River below the Maine paper mills in 2004 was about 28% lower than the 1989 measured color levels (Figure 21). Below the Berlin mill to Rumford, there does not appear to be any significant difference in river color levels attributable to that mill when comparing the 1989 and 2004 data. Background color averaged about 5 color units higher in 2004. The slightly higher color values in 2004 at Shelburne and Rumford appears to be attributable mainly to the higher background color. The increase in river color attributable to the Fraser in Berlin is only about 5 to 6 color units, which is a relatively low amount of impact.

Phosphorus concentrations in Gulf Island Pond can be compared to available historic data (Figure 22). Concentrations entering the pond at the Twin Bridges location are a good indication of potential algae problems that could be experienced within the pond. The total phosphorus and orthophosphorus concentrations entering the pond in 2004 were 38% and 70% lower, respectively, than levels measured in August of 2000. Hence phosphorus entering the pond is much lower now, but levels are still sufficient to cause algae blooms. There was one widespread bloom observed on August 4 and smaller localized blooms observed on three other sampling days. An analysis of the 2004 data will be made to determine whether or not algae levels on the pond have been reduced.

The chlorophyll-a levels measured in Gulf Island Pond in 1998, 1999, and 2000 can be compared to the 2004 data as an attempt to answer this question. If the data are just visually compared (Figure 22), it would initially appear that algae levels in 2004 were lower than 1998 and 1999, but not significantly different than 2000. The levels of algal biomass appear to be less severe in the more infrequent scatter points and lower as a whole. Conditions other than loading affect algae biomass levels. River flow and temperature also affect the amount of algae that could grow in the pond and this information must also be considered. Also the 1998 and 2000 data involved only weekly sampling in August compared to weekly sampling throughout the summer in 1999 and 2004.

River flow and temperature conditions (Figure 23) indicate that 1998, 2000, and 2004 were all relatively cool summers. 1999 was a summer of both warm water temperatures and low flows approaching 7Q10. 1998 was a summer of very high river flow in June and July followed by normal river flow in August. River flows were low in 2004 in June

and the first part of July and flows in August comparable to 1998. Given constant nutrient loads in 1998 and 2004, 2004 should be a year with more severe algae problems. However the August chlorophyll-a data show that 1998 had the more severe algae problems. This may be an indication of improvement.

1999 was a year of extended low flow from June to August and higher water temperatures throughout the summer than 2004. It is difficult to compare the 2004 data to this year. The 1999 data should be a good comparison year to future data involving good critical conditions of high river temperature and low flow.

The monthly average June water temperature in 2000 was about 3 ^{o}C lower than 2004. There was also higher river flows in the summer of 2000 in June and July compared to low flow conditions approaching 7Q10 in 2004. Perhaps the more unfavorable conditions for the growth of algae experienced in 2000 are the reason for the low chlorophyll-a measured in that year. An additional year of chlorophyll-a in the pond should be valuable information to better sort this out.

Finally, the data gathered at the continuous DO monitor at the dam at a depth of 50 feet is plotted with the flow and water temperature data from the years 1998 to 2004 (Figure 23). The number of times minimum DO criteria are not met here is plotted as a column graph. The next shallower depth monitored continuously at the dam is 35 feet, but at this depth, all minimum DO criteria are usually maintained. At a depth of 50 feet, DO non-attainment can be usually observed each year and hence somewhere in-between a depth of 35 and 50 feet is where non-attainment of DO criteria begin. The 50 foot depth is a good comparison point for water quality trends of dissolved oxygen for each year.

The data does not appear to indicate any trend of either improvement or diminishment of DO levels at the 50 foot depth over the last 6 years.

Quality Control

An important component of any sampling effort is the water quality monitoring plan. This is prepared prior to the beginning of field work and is typically reviewed by DEP to assure that the proposed plan will be adequate to satisfy the stated objectives and all DEP SOP's are followed. The monitoring plan was prepared by Acheron, consultants to the paper mills, and is available upon request.

Proper quality control is essential for any sampling effort to assure good data. Quality control procedures were practiced in both field sampling and the laboratory analysis of various parameters. Dissolved oxygen meters were cross checked before and after each sampling run and checked occasionally during the day. If meters did not agree favorably, they were re calibrated and rechecked.

Field duplicate samples were collected for most parameters at a frequency of one location every other week. Field blanks were also prepared using ultra pure distilled water in field sampling equipment after rinsing and analyzed for each parameter at a frequency of one location every other week. This results in an overall coverage of 10% for duplicates and

field blanks. Duplicates samples are compared graphically (Figures 24 to 27) and in tabular form as indicated below.

Table 2 Duplicate Sample Deviation

Parameter	Number	Ave Deviation	% Within Unit of Measurement	% Within 2 Units of Measurement	Unit of Measurement
Field Measurements					
Dissolved Oxygen	107	.06 ppm	94%	95%	0.1 ppm
Temperature	107	.04 ^{o}C	97%	98%	0.1 ^{o}C
Secchi Depth	11	.08 M	82%	91%	0.1 M
Total Field Measurements	**225**	**.51 units**	**95%**	**96%**	
Laboratory Analysis					
Total Phosphorus	11	2.4 ppb	64%	64%	1 ppb
Orthophosphorus	9	0.11 ppb	89%	100%	1 ppb
Chlorophyll a	7	0.37 ppb	100%	100%	1 ppb
Total Kjeldhal Nitrogen	10	0.03 ppm	90%	90%	0.1 ppm
Ammonia Nitrogen	10	0.02 ppm	50%	80%	0.01 ppm
Nitrite + Nitrate Nitrogen	10	0.01 ppm	90%	90%	0.01 ppm
Total Laboratory Analysis	**57**	**1.03 units**	**80%**	**87%**	

It can be seen from the figures that good agreement is achieved in most parameters of the duplicate sampling. The unit of measurement (right hand column Table 2) is the expected level of accuracy that can be achieved with near perfect quality control. The majority of field measurements (95%) is within this accuracy and the average deviation for field measurements was about 0.5 units. The majority of the laboratory analysis (80%) also is within this accuracy and the average deviation for laboratory analysis is about 1 unit.

Field blanks are an important part of quality control to assure contamination not related to actual ambient conditions (example - field or laboratory equipment) is not biasing the analytical results of laboratory analysis. The laboratory results of field blanks should be below detection limits for any given parameter. All of the field blank results (see appendix) were at or below detection limits.

The data collected for the Androscoggin River and Gulf Island Pond are considered to be of good quality.